10/553610
JC12 Rec'd PCT/PTC 18 OCT 2005

Machine Tool Comprising Parallel Tool Spindles That Can Be Repositioned In Relation To One Another

Description:

The invention relates to a machine tool, in particular for the synchronous machining of workpieces, said machine tool being comprised of two or more spindle units in accordance with the generic term of Claim 1.

In multiple-spindle, synchronous machining of workpieces, e.g. with a double-spindle machining module, the distances between machining spindles might be altered due to different effects, particularly due to thermal expansion. These alterations partly might substantially affect the accuracy in workpiece machining, thus making it impossible to warrant the required accuracy during machining any longer in a process-reliable manner.

As compared with synchronously working machines, therefore, machines with separate drives in one or more axes of the machining units were implemented. Machines of this type, for example, have the general conception of a separate z-axis or a separate y and z-axis. Thus it is possible to warrant process-reliability in critical machining situations with regard to tool lengths. A compensation for position with regard to the distance in the plane normally to the spindle axis, however, cannot be brought about thereby. Another possibility to improve accuracy is executing the machining only with one tool with exact machining operations. But the cycle time of machining is thereby increased quite substantially. In some instances the separate spindles are implemented only to reduce ancillary times. According to that approach, tools are exchanged in one spindle, while the other spindle executes a machining process. Though this principle constitutes a viable possibility for reducing the overall time with short times of engagement in the course of which the machining operations take a time similarly long as that of a tools exchange, but the machine-side expenditure is relatively high as compared with its benefit.

Though EP 885 088 B1 discloses a repositioning of a working spindle in relation to another spindle firmly disposed in a housing, this spindle is disposed in its own U-shaped sledge and equipped with costly repositioning devices (gearbox, ball-type rolling spindle, and belt drive).

This repositioning is designed particularly for adapting to different workpieces, i.e. for very large repositioning paths.

Known from the field of turning lathes, too, is a means for adjusting the distance between two spindle units disposed in parallel to each other via a costly ball-type roller spindle for large repositioning paths (JP 62 138 515 U).

DE 198 59 360 A1 discloses a machine tool with a piezoelectrical position correction device, wherein two working spindles are disposed parallel to each other in a machining unit and wherein at least one electrically activated piezoelectrical positioner element is provided for to adjust the distance of the two spindles. The positioner element acts on the housing of the machining unit and can slightly bend apart the two arms which the spindles are affixed to. The positioning path of the piezoelements is very restricted with regard to the existing built space. Besides, the aptness for use of these elements in production machines is critical.

Furthermore, with a multiple-spindle machining, the axial compensation for length of tools (z-direction) should be duly considered. On installation of these tools, they can be adjusted in axial direction only with a certain degree of accuracy, usually measuring their position by the aid of a tool pre-adjustment device and being able to offset values determined with some compensation in a limited range. Here, too, it is only possible with some restrictions to compensate for different lengths of tools. Up to now, these differences can only be realized by utilizing two independent z-axes.

Now, therefore, it is the object of the present invention to propose a repositioning device for a machine tool according to the general conception of this species in which particularly those problems outlined hereinabove do not exist and in which particularly an automatic adjustment to the position of the spindle units is made possible in x and/or y direction.

To solve this task it is proposed that the repositioning device for at least one of the spindle units at least in one x and/or y direction be comprised of an eccentric bush rotatable about a central shaft and lockable, in which the spindle units are eccentrically supported parallel to the central axis.

Sub-claims 2 to 8 contain purposive forms of embodiments for this repositioning device.

As provided for under the present invention, the two spindles disposed horizontally or vertically in parallel axis to each other can be adjusted independently of each other in x and/or y direction in a simple manner by turning the eccentric bushes, in which they are eccentrically supported, around a definable angle. To this effect, the anti-twist securing and/or clamping means of the eccentric bushes within the stationary bracket is released at first so that the eccentric bushes can be turned and/or so that one of the eccentric bushes can be displaced in axial direction. During machining they are firmly arrested and/or clamped in the bracket. The clamping of the spindle units during machining is accomplished by using a clamping ring in the same manner as for example a belt pulley is fastened on a shaft. Thus it is possible to generate high clamping forces within a very restricted built space and the spindle is kept safely in its position even during severe machining.

The repositioning devices can be approached and activated particularly independent of each other. To adjust the eccentric bushes in x and y direction, the repositioning devices attack the eccentric bushes tangentially outside, with it being possible to drive them mechanically, electrically, or hydraulically. For transformation of the linear drive motion into the required rotary motion of the eccentric bushes, the repositioning devices are provided with frictionally-locked transmission links accommodated in grooves, while retainer bolts are mounted preferably at the eccentric bushes in parallel axis to the spindle axis, with grooved blocks actuated by repositioning cylinders engaging into said retainer bolts. Hence, according to the present invention, conventional hydraulic or mechanical axles are utilized for the repositioning itself. The movement of the positioner elements is reduced once more by the eccentric bushes, thus making it possible to implement a very sensitive repositioning movement.

The movement of the repositioning devices, particularly the movement of grooved blocks disposed at the repositioning cylinders and/or of retainer bolts at the outer periphery of the eccentric bushes is picked-up and recorded by an automatic measuring system. The repositioning path in x and y direction lies in a range of several tenths of a millimeter, preferably in a range from 0.1 to 0.5 mm, and in a range from 0.8 to 5 mm in z-direction, with it being possible to control and regulate the repositioning with an accuracy of < 1 µm. As compared with prior art positioner elements based on piezoelectrical actuators, the correction is thereby possible in much broader ranges.

The positioning movement in z-direction can particularly be accomplished by a linearly movable actuator strip, which moves the spindle unit in axial direction via a ring arranged on the spindle housing.

The invention is explained in more detail by way of the enclosed FIGS. 1 to 3 giving some examples, in which

FIG. 1 shows a principle arrangement of two spindle units 2, 3 disposed side by side in parallel axis, demonstrating the efficiency of the eccentric bushes 5, 6 lying in the x-y plane normally to spindle axes B1 and B2;.

FIG. 2 shows a top view on the two side-by-side disposed spindle units 2,3 with the actuator block 9 lying there in between, at which the repositioning devices Vx, Vy, and Vz for repositioning in x, y, and z-direction are arranged; and

FIG. 3 shows a perspective view of a spindle unit 2 and/or 3 of said actuator block 9 and the and 4 pertinent valve block 4.

As schematically shown on FIG. 1, the two spindle units 2 and 3 which are disposed side by side in parallel to each other are firmly arranged eccentrically in an eccentric bush 5, 6 each. The eccentric bushes 5, 6 are mounted in bracket 1 of the machine tool in a bearing pivoting by angles $\alpha 1$ and $\alpha 2$ around central shafts B1 and B2. The central shaft S1 of spindle unit 2, when being in its base position in y-direction, has the eccentricity e1 versus the central shaft B1 of eccentric bush 5, while the central shaft S2 of spindle unit 3 in x-direction has the eccentricity e2 versus the central shaft B2 of eccentric bush 6. By twisting, e.g. eccentric bush 5, within the bracket 1 by an angle $\alpha 1$ around central shaft B1 just by a few angle degrees, the spindle unit 2 is repositioned particularly in x-direction. In the same manner, by twisting the eccentric bush 6, the spindle unit 3 firmly arranged therein is repositioned in y-direction. While the spindle unit 2, when twisted around the central shaft B1, is also repositioned at the same time in y-direction and/or while spindle unit 3, when twisted around central shaft B2, is also repositioned in x-direction, this simultaneous repositioning as a so-called fault of second order is negligible in view of the angles provided for here, preferably just accounting for a few angle degrees.

FIGS. 2 to 4 show the spindle units 2, 3 with their usual design details, wherein only those elements that are important for the object of the present invention are provided with reference numbers. The eccentric bushes 5,6 with the spindle units 2, 3 firmly disposed therein are secured against twisting and axial displacement by the aid of two prior art clamping rings 8 with bracket 1. Clamping is accomplished hydromechanically. The clamping is released to allow for a repositioning. The repositioning devices Vx, Vy, and Vz each are arranged on a unique repositioning block 9, allocating one repositioning cylinder 12 to each repositioning device , said repositioning cylinder being connected via corresponding hydraulic mains 7 to a valve block 4. FIG. 3 gives an example, showing only the repositioning cylinder 12 for the repositioning device Vx. At the end of the piston of repositioning cylinder 12, a grooved block 11 is arranged there which engages into a retainer bolt 10 mounted externally at the eccentric bush 5. In this manner, the linear movement of the repositioning cylinder 12 is transformed into the rotary movement of the eccentric bush 5. Arranged on the side of repositioning block 5 facing the spindle unit 3 is the repositioning cylinder of repositioning device Vy, which is not shown in these figures. Moreover, the corresponding repositioning cylinder for the repositioning device Vz is not shown as an extra. Of the repositioning device Vz, it is merely the actuator strip 13 which is shown here and which has a groove for the ring 14 disposed on the spindle unit 2. Each repositioning is accomplished without any play.

In designing the machine, all repositioning devices Vx, Vy, and Vz were devised as complete NC axles each having a measuring system 15 of its own in order to allow for a direct measurement of the position of a spindle unit 2, 3 with high position resolution. Conventional control modules are utilized to control the movement of hydraulic repositioning cylinders 12. A direct link of corrective movements to each individual tool is possible. The repositioning of the corrective units is not considered in the machine ancillary time. This repositioning is accomplished in parallel to the other positioning movements during a tool change. On making a correction in length of the tools, in particular, it is possible to deposit and save the corrective values in the NC program. Hence, the corresponding length corrective value is considered when calling up the relevant tool.

To pick-up and record the actual positions of the two spindles in relation to each other, the fabricated workpieces and be measured in off-line mode, while it is also possible to pick-up and record the positions of spindles by way of the measurement scans taken-up by the

spindles at certain points of reference. By distributing the correction to both machining spindles, equivalent mechanical properties of both spindles with regard to stiffness are obtained. Furthermore, it is thereby achieved that the entire unit can be accommodated in a minimum built space.

In designing the present invention, considering hitherto known principles, care has been taken to ensure that the repositioning device for the adjustment of spindles can also be retrofitted without substantial expenditure into an existing machine. Hence, the machine properties do not depend on the integration of this unit. With prior art mechanisms, the positioning elements lay directly in the flow of force of the machine and thus influenced the resilience behaviour of the machine.

In conformity with the present invention, the constructional elements applied hereunder are accommodated in a well protected space.

Reference Numbers

1	Bracket
2	Spindle unit (in 5)
3	Spindle unit (in 6)
4	Valve block
5	Eccentric bush (with 2, eccentrically supported therein)
6	Eccentric bush (with 3, eccentrically supported therein)
7	Hydraulic lines
8	Clamping ring (for clamping of 5,6 to 1)
9	Positioning block (for offset in x, y, z direction)
10	Retainer bolt (at 5 for 11)
11	Groove block (at Vx for 10)
12	Repositioning cylinder (at Vx)
13	Actuator strip (of Vz)
14	Ring (at 2 for 13)
15	Measuring system (at Vx)
S1	Central shaft of 2
S2	Central shaft of 3
B1	Central shaft of 5
B2	Central shaft of 6
Vx	Repositioning device (for repositioning in x-direction)
Vy	Repositioning device (for repositioning in y-direction)
Vz	Repositioning device (for axial repositioning in z-direction)
α1	Angle around S1
α2	Angle around S2
e1	Eccentricity between S1 and B1 in y-direction
e2	Eccentricity between S2 and B2 in x-direction